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Updated Classification System for Proximal Humeral Fractures

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Proximal humeral fractures can restrict daily activities and, therefore, deserve efficient diagnoses that minimize complications and sequels. For good diagnosis and treatment, patient characteristics, variability in the forms of the fractures presented, and the technical difficulties in achieving fair results with surgical treatment should all be taken into account. Current classification systems for these fractures are based on anatomical and pathological principles, and not on systematic image reading. These fractures can appear in many different forms, with many characteristics that must be identified. However, many current classification systems lack good reliability, both inter-observer and intra-observer for different image types. A new approach to image reading, following a well-designed set and sequence of variables to check, is needed. We previously reported such an image reading system. In the present study, we report a classification system based on this image reading system. Here we define 21 fracture characteristics and apply them along with classical Codman approaches to classify fractures. We base this novel classification system for classifying proximal humeral fractures on a review of scientific literature and improvements to our image reading protocol. Patient status, fracture characteristics and surgeon circumstances have been important issues in developing this system.

Keywords: Classification system; Diagnosis; Fracture; Humerus; Image; Proximal humeral fractures; Treatment

Proximal humeral fractures (PHF) are a frequent health problem for people of various ages. They can affect quality of life, not only in acute phases, but also permanently, due to sequels. Management of this condition depends on the patient's characteristics, the type of the fracture, technical difficulties in surgical treatment, and the surgeon's circumstances.

Here we focus on classifying the type of fracture, with the aim of improving the basis of planning for treatment. Because many approaches to typing fractures are possible, it is difficult to set up a diagnostic classification system. Previous fracture classification systems[1-3] were based on anatomical and pathological criteria.[4] They show low intra- and inter-observer reliability with plain radiographs,[5-12] even with computed tomography (CT) scan studies[9,12-16] and 3D reconstructions,[9,14] making diagnoses, treatment decisions[3,7,13] and communication among peers difficult.[3,8,14]

When reading images, many characteristics must be observed and taken into account sequentially. As the numbers of characteristics that have to be assessed increases, fracture classification becomes more complex. However, as the amount of information in our fracture database increases, we may better formulate fracture classifications and improve decision-making.[17] On the other hand, detection of a first pathological finding in an image reading exercise is a handicap in detecting other possible pathological findings at the same time.[18] Such handicaps are known as perceptual set effects.[19]

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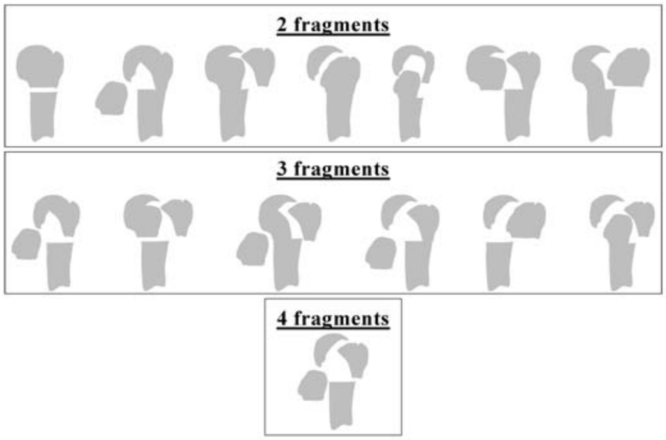

Figure 1. Proximal humeral fracture classification, based on Codman's scheme. Fracture possibilities are grouped by number of fragments present. There are seven types of 2-fragment, six types of 3-fragment, and one type of 4-fragment fractures. Dislocation or articular surface fractures are not included.

Currently, more than 20 different fracture characteristics are considered to be useful in characterizing PHF. Initially, 17 fracture characteristics were grouped in our image reading protocol, which was shown in its first trial to be a valid instrument for characterizing PHF.[20] The objective of the present work is to review the current fracture classifications of PHF and to present a new classification approach and classification system.

The new classification system, based on fracture characterization and using Codman classification graphs, presents a new image reading protocol with 21 fracture characteristics divided into five groups. It assesses and defines every current fracture characteristic and its possible values. As a result, it provides a basis for treatment planning according to the current level of clinical and surgical developments.

METHODS

Review of Scientific Literature on PHF Classification and Characterization

Medline and Cochrane Library were searched for updated works in PHF classification. Studies were selected attending to their interest based on reliability of different classification models and description of the characterization process based on kappa coefficient.[21]

Critical Analysis of our Experience in PHF Characterization

After our previous study on the reliability of the characteristics of the image reading protocol, some changes seemed necessary for complete fracture characterization. Therefore, we revised the previous image reading protocol design and modified it to improve treatment decision-making.

We used Codman's classification system to develop our new protocol because it seems more complete and flexible than other existing systems. It allows for the addition of new fracture characteristics and is better applied to many cases (figure 1). The relationship between elements and fracture planes (a binary relation, as it has been called)[22] is used to calculate the number of possibilities for each number of fragments. Considering the four possible elements (cephalic, greater tuberosity, lesser tuberosity and diaphyseal), fractures can be classified into sets of two, three or four fragments (table 1). The protocol consists of analyzing a set of fracture characteristics following a standard order.

We studied the previously defined fracture characteristics of PHF and their values. We observed several different proposed values for some characteristics in the literature. In these cases we chose the value with more statistical significance or more clinical relevance. We included some new parameters defined in the literature in the last years as important prognostic factors for these fractures. Finally, we included other new fracture characteristics that we consider important for treatment.

New Approach of PHF Classification Based on Characterization

Qualitative analysis has been performed trying to avoid lack in reliability and including new characteristics to take into account when deciding the best diagnosis of a specific fracture. Reliable characteristics of the fracture, including simple X-ray and CT-scan, patient characteristics and surgeon experience, have been considered in the new classification system. It enables classification of these fractures, treatment,

Table 1. Relationship between the Codman system elements and fracture planes.

Fracture fragments	2-fragments	3-fragments	4-fragments
Plane involvement	CTt / D CTD / t CtD / T CT / tD Ct / TD CD / Tt C / TtD	CT / t / D Ct / T / D CD / T / t C / Tt / D C / T / tD C / t / TD	C / T / t / D

C, cephalic element; T, greater tuberosity element; t, lesser tuberosity element; D, diaphyseal element.

and finally, if surgery is needed, provision of the required data for selecting the surgical technique. Different fracture characteristics are used in each process. Although some are not necessary for classification, they are very useful in treatment decision-making.

RESULTS

Background on the Diagnosis and Classification of PHF

Codman defined four anatomic parts (greater tuberosity, lesser tuberosity, articular segment, and diaphysis) of PHF in 1934.[4] Since then, other classifications have been proposed.[1-3,23,24] The two most widely used systems are that of Neer,[1] and that of the Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation.[2]

Evaluations of these classification systems with kappa coefficient[21] reveal low reliability.[5-16] Better inter-observer reliability has only been reported among observers with formal training in the Neer system.[16,25]

On the other hand, new progress in PHF studies, especially in vascularization, allows the definition of important new characteristics for treatment decision-making.[26-30] Because important new concepts for prognosis and treatment of PHF do not easily fit in past classification systems, some authors have proposed new imaging techniques[8,12] or new functional classifications.[14] Since 2003, new systems of fracture classifications have been published.[20,22,31,32]

Hertel[22] presented a structured system for reading images, including 12 questions, which require 3-D image measurements. Fractures were classified using a binary description system combining the four fragments and the five basic planes of the fracture.

In 2006 we published a new image reading protocol of PHF.[20] The main objective of this protocol was to standardize image reading and to take into account the fracture characteristics to be assessed. In this preliminary study, 17 fracture characteristics were defined as relevant. The relevant characteristics were divided into four reading protocol groups: cephalodiaphiseal, cephalotuberosity, cephaloglenoid, and fracture description. The intra-observer and inter-observer reliabilities of each relevant characteristic were assessed from results obtained from four observers. The observers were a first year registrar, a third year registrar and two experienced consultants.

Results showed good inter-observer reliability for relevant parameters of the cephalodiaphiseal group and some of the

Table 2. Image reading protocol for proximal humeral fractures (21 relevant characteristics).

Group	Characteristic
Cephalodiaphyseal relationship	Not impacted/impacted
	Contact, No contact/less than 20%/between 20% and 50%/greater than 50%**
	No displacement/displacement
	Lateral/medial/without displacement
	Varus/valgus/without displacement
	Associated metadiaphyseal fractures. Meta internal/meta external/diaphyseal
	Preservation of internal fulcrum.
Tuberodiaphyseal relationship**	Lesser tuberosity. No displacement/displacement ($\geq$10 mm)**
	Greater tuberosity. No displacement/displacement ($\geq$10 mm)**
Cephalotuberosity relationship	Lesser tuberosity. No displacement/displacement ($\geq$10 mm)
	Greater tuberosity. No displacement/displacement ($\geq$5 mm)
	Large/small ($\geq$ 3 cm)
	Narrow/wide ($\geq$ 1 cm)
	Comminuted/whole
Humeral head and cephaloglenoid relationship	Cancellous bone stock, good/adequate/deficient
	Articular surface fractures (>20%): impression or split fractures
	Humeral head (cephaloglenoid) orientation**
	Humeral head (cephaloglenoid) dislocation**
Fracture fragment description	Number of fragments
	Extraarticular/articular fractures
	Tuberosity fracture: no fracture/ greater tuberosity /lesser tuberosity/both**

** New groups or characteristics included or changed relative to previous set:
Contact is included as a characteristic. Possibilities of associated metadiaphyseal fracture characteristics are defined.
The tuberodiaphyseal relationship group with two new characteristics has been added.
The no displacement/displacement characteristic of the cephalotuberosity relationship group has been removed.
The name humeral head group has been changed to humeral head and cephaloglenoid relationship group. Two new parameters have been added in it (humeral head [cephaloglenoid] orientation and humeral head [cephaloglenoid] dislocation).
The number of parts (in relation to the Neer classification system) has been removed and tuberosity fracture (with or without displacement) has been added in the fracture fragment description group.

cephalotuberosity group using simple radiographs. The comparison of readings of X-rays alone with readings of X-rays plus CT scans showed differences in the following relevant characteristics: lesser tuberosity displacement, number of fragments, number of parts, and extra-articular/articular fractures. Therefore, CT scans allow better assessment of some relevant parameters in characterizing PHF. We concluded that a structured image reading protocol allows better reliability than has been reported for other approaches.[20]

New Image Reading Protocol for PHF

To improve fracture characterization in the present study, some new characteristics have been added or changed. A new image reading protocol is defined (table 2).

From this new image reading protocol, we developed a classification system to enable better classification of these fractures, optimum treatment, and finally, if surgery is needed, provide the required data for selecting the optimal surgical technique. Different fracture characteristics are used in each process. Although some are not necessary for classification, they are very useful in treatment decision-making.

The assessment of relevant characteristics offered in our protocol should probably be revised over time in light of new prospective studies on the definition of prognostic factors in PHF. This protocol is not an endpoint, rather it aims to help the surgeon be aware of the importance of each characteristic assessment.

As different surgeons can interpret fracture characteristics in different ways, a proper definition was considered to be a decisive issue in avoiding doubts arising from the image reading process. For example, the cephalodiaphyseal relationship (impacted/non-impacted) seems easy to define at first glance. However, some authors have classified the impacted fracture into different types.[33] To overcome confusion that may result from the variety of classifications, interpretation rules should be clearly established.

Description of Fracture Characteristics

All the fracture characteristics included in the new protocol have been accurately defined and classified into the following groups:

Cephalodiaphyseal group

<u>Impaction (non-impacted/impacted)</u>
(not defined previously)
The fracture was classified as impacted when 50% or more of the humeral diaphysis surface maintains its contact with the humeral head, and has penetrated into the cancellous head bone.

<u>Contact (no contact/contact)</u>
(not included and not defined previously)
We defined the contact as the proximity between the parts of a two-fragment fracture. We classified the contact between head (with or without fracture tuberosities) and shaft (diaphysis) by applying the same kind of scale that other authors used for impaction[32] (0 for no contact, 1 for <20% contact, 2 for between 20% and 50% contact, 3 for >50% contact).

<u>Humeral head-diaphysis displacement</u>
(no displacement/displacement)
The fracture was classified as displaced when there is a 1 cm displacement in the lateral/medial direction or anterior/posterior direction of the humeral shaft,[1] or a >30˚ varus/valgus angulation of the humeral head in relation to the cephalodiaphyseal angle of the other shoulder,[3-10] or compared to 130˚ because it is the average cephalodiaphyseal angle[34,35] in the sagittal plane (varus/valgus) or in the coronal plane (anterior-posterior).

<u>Longitudinal plane displacement</u>
(lateral/medial/without displacement)[1]
The fracture was considered as a longitudinal plane displacement when there is a 1 cm displacement in the lateral/medial direction or anterior/posterior direction of the humeral shaft.[1]

<u>Angular displacement</u>
(varus/valgus/without displacement)[3-10]
The fracture was considered as an angular displacement when there is a >30˚ varus/valgus angulation of the humeral head in relation to the cephalodiaphyseal angle of the other shoulder,[3-10] or compared to 130˚ because it is the average cephalodiaphyseal angle[34,35] in the saggital plane (varus/valgus).

<u>Associated metadiaphyseal fractures</u>
(not defined previously)
Presence of metaphyseal fractures is defined when there is one fragment or comminute (two or more fragments) with a surface >10 mm. We must differentiate between fractures that involve internal and external cortex. The association of diaphyseal fracture is present normally with spiral shape and large third fragment.

<u>Preservation of internal fulcrum</u>
We consider a preservation of internal fulcrum when there is continuity between the internal cortex of the humeral head and the diaphysis.

Tuberodiaphyseal group

<u>Tuberosities-diaphysis displacement</u>
(not included and not defined previously)

- Greater tuberosity displacement (no displacement/displacement)
  Displacement ≥10 mm in the posterior or proximal directions of the greater tuberosity, as an independent fragment in relation to the humeral shaft.
- Lesser tuberosity displacement (no displacement/displacement)
  Displacement ≥10 mm in the anterior or proximal directions of the lesser tuberosity, as an independent fragment in relation to the humeral shaft.

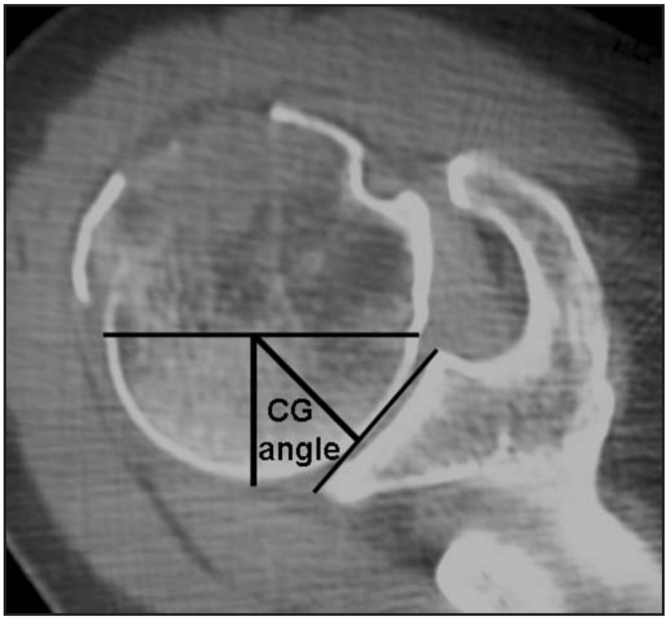

Figure 2. Humeral head orientation: cephaloglenoid angle. This angle is formed by the perpendicular line of the articular surface of the glena (in the horizontal plane), and the line resulting from joining the mean point of the diameter of humeral head semi-circumference with its articular surface apex (most prominent articular surface point). CT scan, axial view.

Cephalotuberosity group

Tuberosities-humeral head displacement

- Lesser tuberosity displacement (no displacement/ displacement)[1,10]
  Displacement of the lesser tuberosity in relation to the head or the head over the lesser tuberosity ≥1 cm.
- Greater tuberosity displacement (no displacement/ displacement)[10,36,37]
  Displacement of the greater tuberosity in relation to the head or the head over the greater tuberosity ≥5 mm.

Tuberosities-greater tuberosity status[20]

- Size (large/small) (longitudinal axle): A large tuberosity fragment is defined as ≥3 cm.
- Width (narrow/wide) (transversal axle): A wide tuberosity fragment was defined as ≥1 cm.
- Fracture involvement (broken/comminute/whole): A whole tuberosity was defined by the lack of a discernable fracture line in the greater tuberosity.

Humeral head and cephaloglenoid group

Cancellous bone stock[20] of the head was analyzed and three types were defined.

- Good: The cancellous bone goes beyond the semicircle forming the articular surface of the humeral head.
- Adequate: The cancellous bone is at the level of the articular semicircle.
- Deficient: The cancellous bone does not reach the semicircle edge.

Articular surface fractures involvement

- Split fracture:[1] The articular surface is fragmented into a number of separated pieces and at least 20% of the articular surface is affected.
- Fracture impression:[1,3] The evolution of the bone lesions described by Hill and Sachs[38] and McLaughlin[39] is secondary to gleno-humeral dislocations affecting articular surface. The fracture impression is type 1 when it affects at least 20% of the articular surface, type 2 when it affects between 20% and 50%, and type 3 when it affects more than 50%. The marginal portion of the humeral head is affected.
- Metaphysodiaphisary impression fractures have been defined by Duparc.[3]

Humeral head (cephaloglenoid) orientation

(not included and not defined previously)

The orientation is defined as the relationship between the articular surface of the humeral head and the glena, as long as there is no dislocation. CT scan axial view classification: antero-posterior relationship with the arm in neutral rotation. Considering the cephaloglenoid angle (figure 2), apex (most prominent articular surface point), and relationship, three types are defined (figure 3):

- Good: The apex is in front of the glena and the cephaloglenoid angle value is between 0˚ and 20˚.
- Sufficient: The apex is without contact with the glena, the relationship between humeral head and glena is preserved, and the cephaloglenoid angle value is between 20˚ and 45˚.

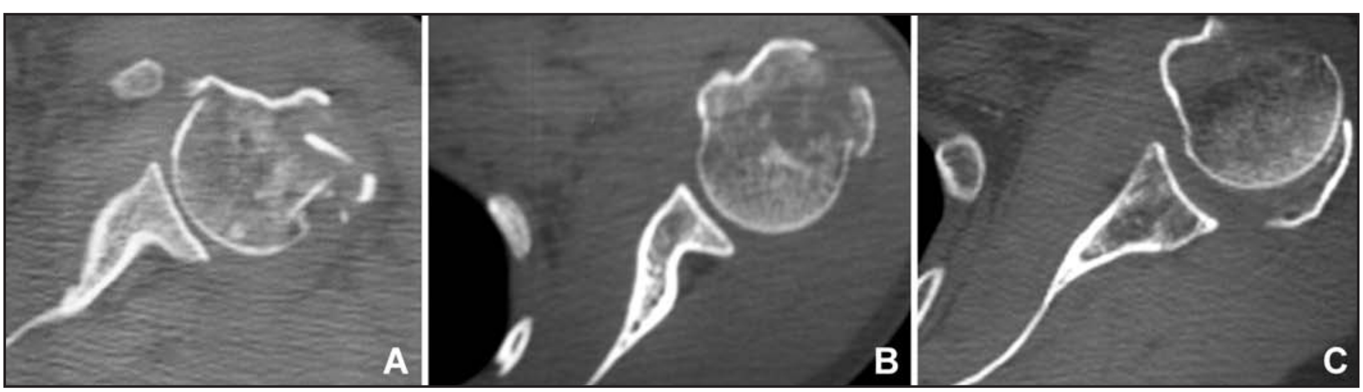

Figure 3. Classification of humeral head orientation. (A) Good, cephaloglenoid angle between 0˚ and 20˚ (CT scan, axial view); (B) Sufficient, with cephaloglenoid angle between 20˚ and 45˚ (CT scan, axial view); (C) Deficient, cephaloglenoid angle >45˚ (CT scan, axial view).

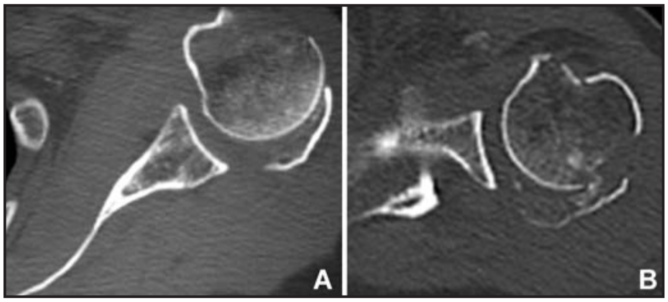

Figure 4. Humeral head orientation in relation to greater tuberosity fracture displacement. (A) Lack of contact between both joint surfaces in the axial plane means a full fracture of one or both tuberosities, leaving dominion to the antagonist muscle, and a non-impacted cephalodiaphyseal relationship. This fracture frequently involves the greater tuberosity with the humeral head in 120˚ retroversion in the epicondilean-epitroclear axis, and a 90˚ apex posterior rotation due to subscapular muscle tendon forces. (B) The sufficient orientation of the humeral head with a posterior displacement of the greater tuberosity implies a cephalodiaphyseal impactation. CT scan, axial view.

- Deficient: The apex has no contact with the glena. There is partial or total loss of relationship between humeral head and glena, although the head is in the joint, and the cephaloglenoid angle value is >45˚.

The relationship between the humeral head and the greater tuberosity is independent of the humeral head orientation (figure 4).

<u>Humeral head (cephaloglenoid) dislocation</u>

(not included and not defined previously)

Dislocation was defined by loss of contact of the humeral head with the front plane of the glena, or the diaphysis is interposed between the humeral head and glena.

- The dislocation is anterior if the humeral head is anterior to the front plane of the glena.
- The dislocation is posterior if the humeral head is posterior to the glena.
- The dislocation is lateral even if the head is in the front plane of the glena, as long as the head has rotated 180˚, the apex is on the opposite side of the glena, the head is on the external side of the diaphysis, and the diaphysis is interposed between the humeral head and the glena (figure 5).

Fracture fragment description group

<u>Number of fragments</u>

The fragment description was based on the four anatomic parts defined by Codman,[4] although there was no displacement.[12,22]

<u>Articular involvement (articular/extra-articular)</u>

A fracture is considered to be articular or intra-articular when the anatomical neck is involved, with or without displacement, regardless of the fracture and the displacement of the tuberosities described by Duparc.[3] In the other cases we consider the fracture extra-articular.

<u>Tuberosity fracture</u>

(not included and not defined previously)

Fracture of the tuberosities from the head and the diaphysis are defined as tuberosity fractures, independently of whether there is a displacement or not. The four possible types are no fracture, greater tuberosity fracture, lesser tuberosity fracture, and greater and lesser tuberosity fracture as a fragment.

The image reading protocol should follow this reading order.

Classification System Based on the New Image Reading Protocol

Once the fracture characteristics have been well designed, we should have a global classification and support for a therapeutic decision-making system that takes patient and fracture characteristics into account. First, the patient must be considered, and then the fracture characteristics must be used to characterize the fracture, to classify it, to indicate a treatment, and to choose the surgical technique when needed. Finally, the surgeon decides the treatment based on his/her circumstances.

Patient characteristics

Patient characteristics, such as co-morbidities and physical health status, including previous quality of life and osteoporosis assessment, should be the first considerations in the decision-making process. Age should be considered in biological, not chronological terms, as there has been an increase in the incidence and severity of PHF in recent years in older people,[33,40-42] mainly women older than 80 years.[33,41,43-45]

Osteoporosis must be considered to establish the proper treatment, including the surgical techniques. Osteoporosis is an important factor in patients with these fractures, especially elderly women. Different studies have demonstrated that many PHF are osteoporotic fractures (for patients over 60 with moderate trauma).[42-53] The age/osteoporosis combination creates bone fragility and more severe PHF.[42-44,46,54] This must

Figure 5. Humeral head lateral dislocation. The humeral head apex is on the opposite side of the glena. X-ray, AP view.

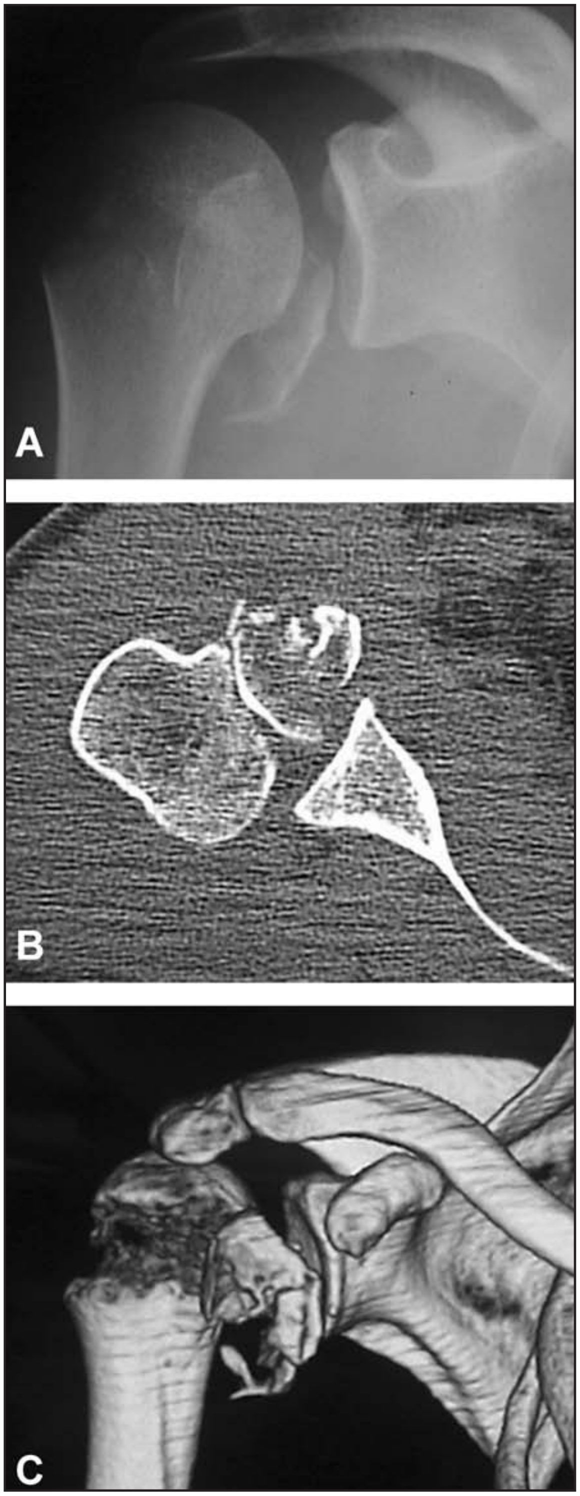

Figure 6. Fracture classification cephalodiaphiseal/T/t (CD/T/t). Fracture of three fragments with conservation of the cephalodiaphyseal relationship and fracture between both tuberosities. This type of fracture is not described in any current classification or in Hertel's graph. (A) A fragment can be seen in the gleno-humeral joint in this X-ray view. (B) A CT scan shows a bigger anterior articular fragment. (C) A 3-D image shows the conservation of the cephalodiaphiseal relationship with a fracture of the tuberosities. Images provided by Dr. C. Torrens of Hospital del Mar (IMAS-IMIM), Barcelona, Spain.

be taken into account as treatment of osteoporotic fractures represents an important health care cost.[55,56]

Poor health status may influence treatment selection, though lack of treatment can convert an independent patient into a dependent one. About two-thirds of patients with PHF are active and live alone, despite their advanced age.[44]

Stimulus to recovery, attitude, and expectations for shoulder restoration and quality of life must be kept in mind. A positive attitude is related to quicker rehabilitation. These factors can be difficult to assess in the emergency department, especially for aging patients who are in pain. When difficulties with rehabilitation treatment are foreseeable, and functional use of the superior limb seems enough for patient's daily life, surgical treatment must be carefully considered.

Associated acute ruptures, the presence of chronic ruptures, and tendon and muscular characteristics of the rotator cuff should be evaluated for the functional prognosis of a good shoulder in deciding the treatment.

Characterization of the fracture

We characterize the fracture using all image reading protocol fracture characteristics. To classify the fracture, three fracture characteristics must be defined. For therapeutic indications, 6 concepts and 12 fracture characteristics are needed. If the patient needs surgical treatment, the rest of the fracture characteristics must be analyzed for selection of the correct surgical technique.

Fracture classification

We base our classification system on Codman's graph system[4] of fracture definitions. Codman's description of the four fragments is still useful and valid for characterizing PHF, as Hertel observed.[22] However, there are some problems with Codman's classification system. For example, Codman's system does not indicate whether the fracture is displaced or not, and whether there are dislocations and articular surface fractures. Therefore, the Codman's classification may be incomplete for guiding the choice of treatment. We aim to overcome this shortcoming by considering more data in the classification system. To include all possible fractures, we classify according to the fracture characteristics item: the number of fragments, fractured tuberosities, and articular/extra-articular involvement.

When there are two fragments, the level of the humeral surgical neck fracture (high or low) or the tuberosity fracture should be described. When the tuberosities are not completely fractured (not fractured to the head and the diaphysis), and there is no articular involvement, the tuberosities are joined one to the head and the other to the shaft. Using the naming scheme T (greater tuberosity), t (lesser tuberosity), C (cephalo or articular segment) and D (diaphysis), there are two possibilities: cephalotuberosity/tD (CT/tD) or cephalotuberosity/TD (Ct/TD). Other cases are when there is no fracture between head and diaphysis, and the tuberosities are fractured in one fragment cephalodiaphiseal/Tt (CD/Tt), or in two (fracture of three fragments).

When there are three fragments, fractured tuberosities in relation to humeral head and diaphysis must be recorded. A special case is when there is no fracture between head and diaphysis, and the tuberosities are fractured in two fragments (cephalodiaphiseal/T/t) (figure 6). When there are four fragments, no more data are need. Finally, articular or extra-articular involvement must be defined.

Therapeutic prescription

Treatment prescription should be based on both patient characteristics and fracture characteristics. Concerning therapeutic prescription, 6 concepts and 12 main fracture characteristics must be used as a reference: impaction, contact, displacement of all fragments (7 fracture characteristics), humeral head orientation or dislocation, and articular surface fractures. Correct assessment of these characteristics avoids confusion as to whether the fracture is impacted or non-impacted, especially when displacement must be considered. Although these criteria are clear with respect to current evidence, new data (especially data concerning functional expectations for elderly patients) may require future changes in the criteria.

Surgical technique selection

Fracture characteristic definitions (i.e., associated metadiaphyseal fractures, greater tuberosity status, humeral head bone stock, articular surface fractures involvement and number of fragments) and also the bone quality (i.e., osteoporosis) are useful in selecting the immediate surgical technique. Other fracture characteristics, such as the preservation of the internal fulcrum and the internal metaphyseal prolongation of humeral head, are also needed for determining the preferred surgical technique and the prognosis. An effective surgical treatment should not be denied to elderly autonomous patients.[57]

DISCUSSION

Image Diagnosis

The most important reason for inaccurate fracture characterization is that all current classification systems of PHF are anatomic and pathological (based on Codman's system) and not radiographic, as Neer points out.[58] A classification system that is adapted to image reading does not exist.

Evaluations of the current classifications with plain radiographs reveal low inter-observer reliability and only moderate intra-observer reliability.[5-12] Different reasons have been documented which explain this low reliability in relation to imaging techniques,[8,12] observers,[7,9,14] image reading,[13,18,19] and the design of these classifications.[3,36,37,59-61] Better inter-observer reliability has only been reported among observers with formal training in the Neer system.[16,25] Using the current classification schemes, CT scans do not improve the reliability of classifications when used in conjunction with X-ray images.[9,12,13,16] Even using 3-D reconstructions does not seem to improve reliability.[9,14] However, when the fracture characteristics are analyzed without classification, the reliability improves with CT scans for some characteristics.[20] For this reason, we recommend classification with X-rays for two-fragment fractures, and CT scans for all the fractures with more than two fragments.

Classification Reliability

Classifying a fracture is an abbreviated way of describing the fracture configuration, and in this synthesis process, information is lost. Reliability results of PHF classifications are low, as it has been shown in several widely used fracture classifications,[62-66] and in medical classification in general.[66,67]

Treatment Decision-Making

Nowadays, the main problem is still the lack of evidence-based studies that clearly state which fracture displacements should be reduced and stabilized. Some studies have demonstrated that agreement in treatment decision-making is better than reliability in classification,[12] and may be due to surgeons' practices of basing their decisions on the descriptions of the fracture characteristics and not on the classifications of the fractures. Detailed radiographic description is the most accurate and easily understood means of conveying information about a particular fracture.[68] This can be seen in recent works on treatment of impacted PHF[69] showing how high-level studies rely on analysis of an independent characteristic (impacted fracture), without reference to current classifications.

There are few randomized controlled trials (RCTs) in the orthopedic literature,[68] including the literature on surgical treatment of fractures.[70] Systematic reviews that included only RCTs can be found in the Cochrane Library. However, there is only one meta-analysis of PHF treatment, and it shows both methodological and clinical deficiencies.[71] Because of the lack of RCTs, non-randomized studies are included in systematic reviews to provide an overview of the best-available evidence.[72] We agree with the authors of Cochrane Library when they demand good quality evidence concerning the treatment of PHF.

The Need for a New Classification System

Finally, the main question is, is a new classification system necessary? Many authors have discussed this issue,[66,67,73-75] and conditions for a good new classification system have been published.[15,67,76]

There is a paradoxical situation. Fracture classifications are used in clinical orthopedics to guide treatment, estimate prognosis, and predict complications, and also to provide a means to store information and document clinical research.

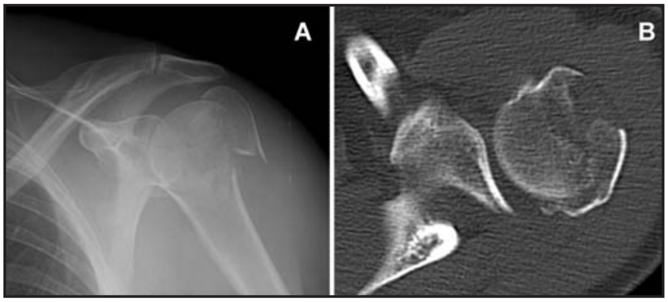

Figure 7. Tuberodiaphyseal and cephalotuberosity relationship. (A) In this X-ray view, a displacement of the head in relation to the diaphysis and displacement of the greater tuberosity in relation to the diaphysis can be seen. The internal fulcrum is not maintained. However, this is an impacted fracture. (B) This CT scan view shows placement of the greater tuberosity in relation to the humeral head with a good cephaloglenoid relationship (impacted fracture).

Reliable, accurate and validated classification is critical, but at this moment it is not possible.[66] As it has been demonstrated, the current PHF classification systems do not obtain a good reliability,[5-16] and therefore it does not seem logical to carry out clinical research based on these current classification systems.

It has been demonstrated that there are multiple possibilities for fracture patterns in the distal tibia,[66] and also in other bone fractures.[67] This indicates that generating newer classification schemes does not address or resolve the need for better classification if we continue to use the same types of classification systems. An updated system for description and characterization of fractures seems necessary.

We propose deconstruction[77] in place of synthesis in upgrading the classification process. We consider the necessary deconstruction to be a new fracture characterization as the basis of a new classification system. In this process every fracture characteristic and its values are defined, and the use of every characteristic (classification, treatment indication and surgical technique) is also indicated.

When fracture characterization is carried out, many characteristics must be observed and taken into account sequentially. The larger the amount of information in a database, the better to obtain optimal fracture classification and treatment decision-making. On the other hand, when the observers have to remember more than five factors, the interpretation reliability is reduced.[17] If characterization is considered as the basis of the new classification system, the observers require an image reading protocol, which can be used by experienced and non-experienced shoulder surgeons.

Therapeutic Indication

It is important to distinguish between impaction and contact because complete contact between fragments can exist without fracture impaction. This describes a non-displaced fracture, which is not stable. Impaction must give a clear concept of stability, which is not a radiographic term. Therefore, we consider a fracture as impacted only when it shows more than 50% contact between both fragments. Impaction degrees, defined previously, are not very useful. However, the same criterion can be used to define contact degree.[32,33]

A displaced fracture has difficult consolidation, and can lead to functional limitation. This cannot be forgotten. Although the patient's age is an important factor in functional recovery expectancies, the displacement concept should not be changed by the patient's age. Such basic concepts must be settled for every fragment in order to identify displacements properly. Final treatment, including whether surgery is needed or not depending on the patient's status, should not depend on an inadequate diagnosis process.

Neer[78] defined his displacement criteria (angulated more than 45˚ and displaced over 1 cm) with the following caveat: "being a guide to the surgeon this should not be considered exactly; it must be considered as a good advice or even a good guideline, but never an evidence-based rule."[78]

We follow Neer's criterion for longitudinal displacement.[1] However, some authors consider that in elderly patients, with only a minimum contact between the humeral head and the diaphysis, non-surgical treatment could be enough. This seems a contradiction, suggesting that we change our indication depending on the patient's age, as Flatow[79] suggests.

Concerning cephalodyaphiseal fractures, the average cephalodiaphyseal angle has been established to be 130˚.[34,35] The definition of the α angle, formed by the perpendicular to the diaphysis and the plane of the humeral head and its prognostic value when it is <20˚, indicates a possible angular displacement of these fractures without functional (clinical) sequel.[10] Therefore, we changed the previous Neer criteria of 45˚ displacement to 30˚ in our protocol.

Concerning tuberosities, many people insist that head displacement is critical. However, we consider the relationship of the tuberosities with the diaphysis more important because if there is no displacement, tuberosities will have good consolidation, and an orthopaedic sleeve will give good performance. If there is displacement in relationship to the diaphysis and the tuberosities, the function may be seriously impaired and the tuberosities may be consolidated in a bad position, producing one of the worst sequels of a fracture[80] (figure 7). There are some fractures defined as valgus impacted four-fragment fractures, in which the tuberosities are almost non-displaced, and the humeral head is displaced. Certainly, these fractures are not correctly classified (figure 8).

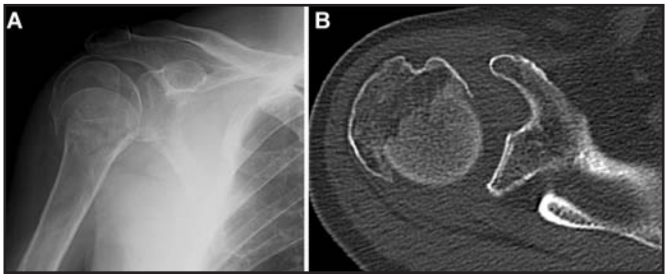

Figure 8. Four part valgus fracture = three fragment fracture C/D/Tt. The possible four-part valgus fracture is converted to a three-fragment fracture with only one fragment displaced, the humeral head. (A) The tuberodiaphyseal relationship is greater tuberosity without displacement. The cephalotuberosity relationship is displacement of the head in relation to the tuberosities but not the tuberosities. The cephalodiaphyseal relationship is impacted and displaced fracture in valgus of the humeral head over diaphysis with internal fulcrum conserved. X-ray, AP view. (B) There is no fracture between tuberosities here. The classification is C/D/Tt. There are three fragments, articular, without fracture between tuberosities. This type of fracture is not very frequent but it is possible, and is included in the fourteen possible upper humeral fractures. The cephalotuberosity relationship is humeral head displacement. CT scan, axial view.

As to cephalotuberosity characteristics, recently published works on greater tuberosity displacement in young and adult patients are interesting. We believe that a displacement of more than 5 mm of this tuberosity needs reduction and fixation in young and adult patients.[10,36,37]

In regard to cephaloglenoid characteristics, especially in dislocation fractures, when the head is located in the external part of the humeral diaphysis, it is clearly out of the glenohumeral joint. Lateral dislocation fractures in four parts were defined by Neer[78] but not classified. Dislocation fractures can be impacted or non-impacted, and they need reduction and fixation.

As to humeral head orientation, analyzed by CT scan, we consider that loss of contact between joint surfaces requires surgical treatment. In a radiological study, Tamai et al[59] indicates that only in type M (medial) fractures, when the head articular surface has some contact with the glena, the head has soft tissue insertions. After further research, Hertel[22] observed that type S (superior) fractures of the Tamai classification (corresponding to four-part fractures) impacted in valgus when a conserved internal fulcrum is shown, having an internal metaphyseal prolongation fragment conserves the insertion of the capsule and posteromedial arterial supply (figure 9). In these cases osteosynthesis is possible.

Surgical Technique Selection

Good bone quality in patients allows a wide range of techniques in fracture treatment, which is useful for obtaining the best functional performance results. Poor bone quality, (e.g., osteoporosis in elderly women) especially when associated with severe fractures, should be considered when choosing surgical techniques preoperatively, or in the operating room. Recent studies that compared systems of osteosynthesis of the humeral head in osteoporotic bones show that the best syntheses are the elastic ones, and different techniques have been proposed.[81-84] However, studies do not mention the amount of humeral head bone stock needed, or whether associated non-displaced fractures of tuberosities can influence the results.

Internal fulcrum and posterointernal metaphyseal prolongation of the humeral head help the maintenance of humeral head vascularization in fractures of three and four fragments, leading to a favorable survival prognosis of the humeral head.[22] Keeping the internal fulcrum in valgus fractures favors both mechanics and vascularization in surgical treatment.[81-84]

The characteristics of the greater tuberosity[20] have to be assessed for the treatment of an isolated fracture, and for a fracture with three or four fragments, because the surgical treatment prognosis depends in some cases on the greater tuberosity.[85]

The number of fragments in a fracture must be considered. Behavior of an extra-articular fracture of two fragments (surgical neck) displaced, without tuberosity fracture, is different from a four-fragment fracture, displaced on the cephalodiaphyseal level with a correct cephalotuberosity relationship. These fractures, defined as two-part fractures by Neer, require different treatments. In the first case, there will normally be a conserved epifiso-methaphiseal cancellous bone structure and a large fixation area because there are no fractures lines. In the second case, the fixation area is reduced to the humeral head because there are tuberosity fracture lines, which weaken the metaphyseal zone.

SUMMARY

The goal of this work has been to present a new approach to PHF classification based on characterization. We use an

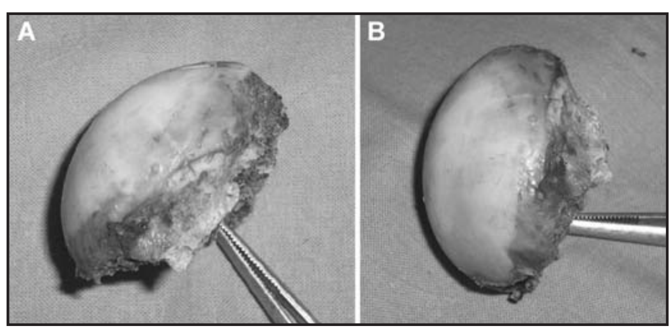

Figure 9. Metaphyseal prolongation. This image shows the posteromedial metaphyseal fragment prolongation of the humeral head, which allows an insertion of the posteromedial capsule (as shown in the patient's surgical intervention). (A) Frontal view. (B) Lateral view.

image reading protocol for fracture characterization. Analyzing the fracture characteristics of this protocol and putting them in order, a new classification system is obtained. This PHF-classification system should facilitate improved treatment decision-making. In addition to the general orthopaedic surgeons at emergency trauma departments, specialized shoulder surgeons can benefit by using this classification system.

In relation to the patients, it seems necessary to divide these fractures in two groups, fractures in elderly dependent patients and fractures in active independent patients, and to define different measures of displacement and treatment criteria for each of these two groups.

In regard of fracture characterization, we consider the impaction/no impaction characteristic of the cephalo-diaphyseal group and the displacement, especially the tuberosities displacement of the tuberodiaphiseal group, as the most important characteristics, in relation with the treatment decision-making. For the surgical technique selection in the complex PHF, the internal fulcrum preservation and the cancellous bone stock of the humeral head are the most important characteristics currently for us.

While formulating a treatment guideline for PHF is difficult, it is mandatory to characterize these fractures correctly. Ultimately, the choice of treatment must be based on experience and circumstances. To recommend the orientation of treatment, based on better “know-how” and fracture characterization, is more than logical and reasonable, it is necessary. Lack of evidence-based studies hinders the establishment of which treatment, nonsurgical or surgical, and which surgical technique is best for treating each PHF. This should be our common task in the future.

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